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**SUPPLEMENTAL GROUNDWATER TRACING STUDY WORK PLAN  
ARKWOOD SUPERFUND SITE, OMAHA, ARKANSAS**

**August 27, 2014**

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A work plan prepared for Ms. Jean Mescher, McKesson Corporation, One Post Street,  
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## Introduction

The Arkwood site is located on relatively flat-lying Boone Formation of Mississippian age. The Boone Formation is comprised primarily of limestone and chert and the abundance of chert varies both laterally and vertically within the formation.

The epikarst is the weathered zone in the upper part of the bedrock. This zone in the Boone Formation is often about 30 feet thick with the abundance of solutional voids decreasing with depth. Residual wastes at waste sites in karst landscapes are commonly detained within the epikarst (also called the epikarstic zone).

In 1991 the Ozark Underground Laboratory (OUL) conducted a comprehensive groundwater tracing study at the Arkwood site with extensive off-site sampling. Dyes for that study were introduced at locations that bracketed the site. One trace was introduced south of the former Woodchip Pile and the second was introduced into the flow from New Cricket Spring. A total of 79 sampling stations were monitored during the 1991 dye tracing study. Dye from the Woodchip Pile trace was detected at 12 stations in the Walnut Creek basin and dye from the New Cricket Spring trace was detected at 14 stations within or near the channels of New Cricket Spring Branch and Cricket Creek.

When the facility was in operation, PCP contaminated wastes were dumped into a sinkhole located roughly in the middle of the site. As much debris as possible was subsequently removed from the sinkhole, it was grouted with concrete and capped with clean topsoil. Several shallow wells into the epikarstic zone were later drilled surrounding the sinkhole area and ozonated water was introduced into some of them to accelerate waste treatment being provided for water discharging from New Cricket Spring.

Nine wells were drilled in the vicinity of the former sinkhole. The purpose of these wells was to inject ozonated water to enhance treatment of residual wastes detained in the epikarst. The injected water was also designed to ensure that New Cricket Spring would always have a sufficient flow rate to allow the treatment plant to operate properly. The rate at which individual wells could accept water varied from less than about 1 gallon per minute to 35 gallons per minute or more. Rates of water acceptance decreased with time at some of the wells.

In March 2014, McKesson Corporation hosted a tour of the site and facilitated on-site discussions for involved personnel from U.S. EPA and Arkansas Department of Environmental Quality (ADEQ). One topic raised during the tour and discussions was the potential benefit of conducting a semi-quantitative dye trace from the vicinity of the former sinkhole to New Cricket Spring. Such a trace would provide data about water movement from that portion of the site most heavily impacted by PCP wastes and associated dioxins to the primary point where contaminated groundwater discharged to the surface. This work plan outlines how such a tracer study would be conducted.

## Study Design

Two tracer dyes will be utilized at the same time to conduct the tracing study. Fluorescein and rhodamine WT dyes are ideal for use at the site since their emission fluorescence peaks are substantially different and thus do not interfere appreciably with one another unless concentrations of one dye produce a fluorescence peak more than about two orders of magnitude greater than the other. This is not expected at the site.

Prior to any dye or water introduction we will measure the depth of the wells and determine if there is any standing water in the selected wells. If there is water present, we will measure the depth to water below ground surface.

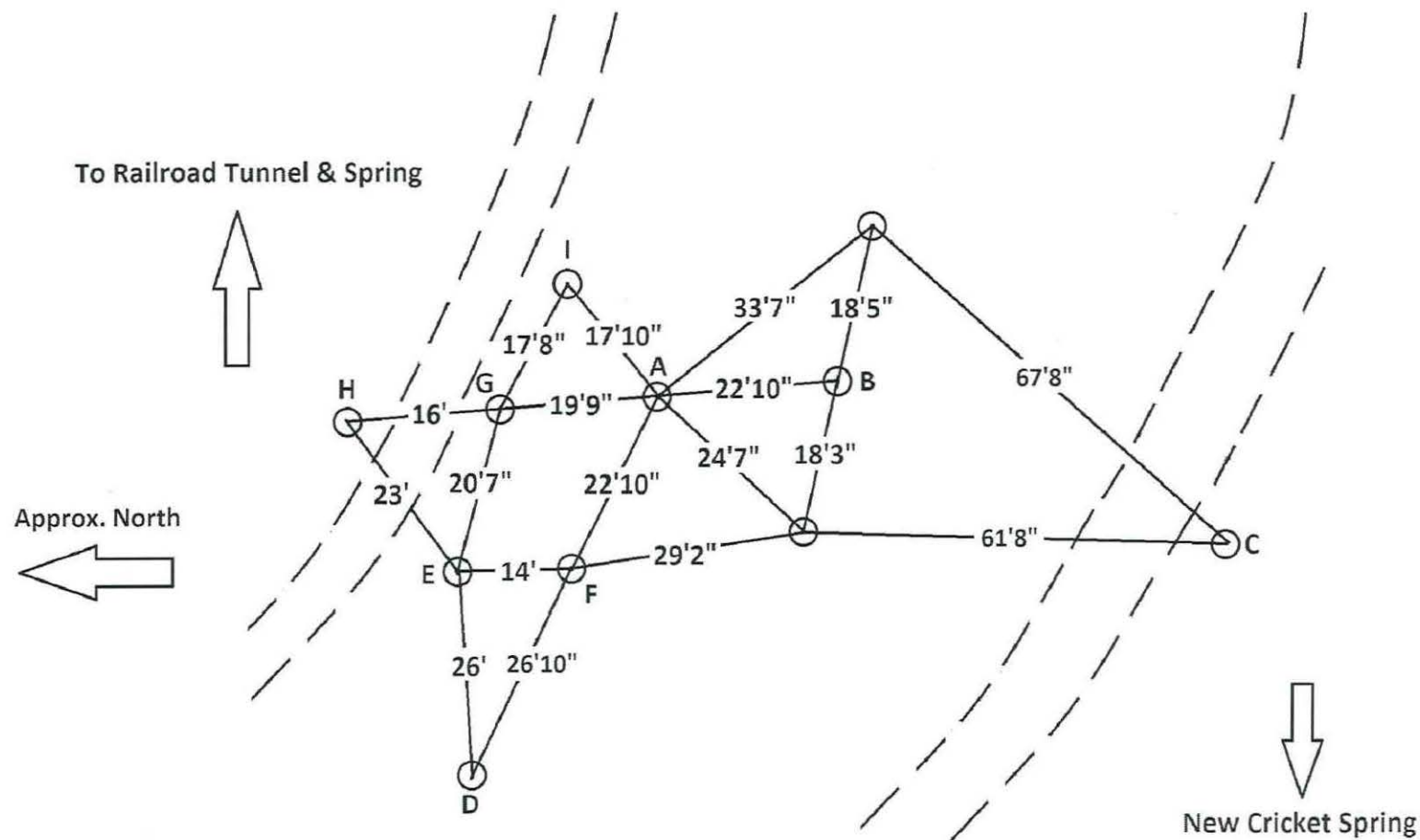
The wells planned for dye introduction are wells A and B. Both wells are located in the vicinity of the former sinkhole. Prior to any dye introduction we will test wells A and B with about 200 gallons of water in each to verify that they will readily accept water. We anticipate that these wells will readily accept water, but will select an alternate well in the unlikely event that this is necessary. Figure 1 is a sketch of the well locations. New Cricket Spring is northwest of the wells and is about 1,200 feet from the middle of the group of wells. Water for testing the wells and for the dye introductions will be from the deep well on site; it has a reported capacity of about 35 gallons per minute.

One pound of fluorescein dye mixture containing about 75% dye equivalent (a powder mixture) will be mixed with about a gallon of water and introduced into Well A. Four pounds of rhodamine WT dye mixture containing about 20% dye equivalent (a liquid mixture) will be introduced into Well B. Each of the dye introductions will be flushed with approximately equal volumes of water derived from the deep well on site. This well can deliver approximately 35 gallons per minute. The existing pipe or a hose will be run from the deep well to Wells A and B. As much water as possible will be introduced into these wells during a one-day work period. As an estimate, if we can deliver about 35 gallons of water per minute, and can do this for about 5 hours, this would represent a total volume of about 10,000 gallons of water or about 5,000 gallons for each well. A minimum volume of water for each well will be about 2,000 gallons.

New Cricket Spring will be the primary dye sampling station. An ISCO programmable automatic pumped sampler will be installed at the spring (hopefully inside the treatment building). It can collect up to 26 bottles of water before servicing. It will be programmed to collect water samples as follows:

- ❖ Three bottles of water per day for the first week after dye introduction. Each bottle will contain a composite water sample consisting of eight equal volumes of water collected at one-hour intervals.
- ❖ Two bottles of water per day for the next six weeks. Each bottle will contain a composite water sample consisting of six equal volumes of water collected at two-hour intervals.

Figure 1. Sketch map showing the relative location of nine wells in the vicinity of the former sinkhole.



We anticipate that most of the dye that discharges from New Cricket Spring will pass through the spring within 7 weeks of the time of dye introduction. In the event that sample analysis after the first 4 weeks of sampling indicates that the duration of a major portion of the dye pulse is likely to last longer than seven weeks, we will recommend that the study be extended for one or more three-week sampling cycles.

Activated carbon samplers will also be placed at New Cricket Spring as control samples. They will be collected and new samplers will be placed each time a trip is made to the site to service the ISCO sampler.

To verify that no dye discharges at locations other than New Cricket Spring, the following locations will be sampled with activated carbon samplers and grab samples of water:

- ❖ Cricket Spring (located downstream of New Cricket Spring)
- ❖ Water discharging from the south end of the railroad tunnel and, depending upon flow conditions, at one or two additional sites in upper portions of the Walnut Creek Valley. This assumes that access to the area can be obtained.

Tracer dyes will be introduced in two of the nine wells near the former sinkhole. The other seven wells will be sampled for tracer dyes each time the ISCO sampler is serviced. This sampling will use activated carbon samplers (which sample continuously) and grab samples of water. Sampling will use bailers dedicated to each well; activated carbon samplers will be attached to the bailers. Water samples will be analyzed only if one or both of the dyes is detected in the associated activated carbon sampler. These data will help assess water movement among wells in the epikarstic zone.

Continuous flow records will be collected at New Cricket Spring except when the flow rate exceeds 650 gpm. When flow is greater than 650 gpm, the excess flow passes through a 90-degree V-notch weir for which there is a rating table and can be manually recorded up to approximately 1300 gpm. A pressure transducer will be used during the study period to record water depth upstream of the weir. Through a combination of the two types of flow records we will be able to determine the total flow <sup>1</sup> rates from New Cricket Spring during the study period. These flow rates, multiplied by dye concentrations will permit calculation of the cumulative mass of dye discharged through New Cricket Spring.

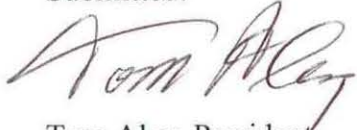
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<sup>1</sup> Aley, Thomas 1997. *Groundwater Tracing in the Epikarst*, Springfield: Proceedings of the Sixth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst, 1997. Copy attached for reference

## Reports

A final report will be prepared at the completion of the study. The report will include all relevant data including dye analysis results.

Submitted:

A handwritten signature in dark ink, appearing to read "Tom Aley". The signature is fluid and cursive, with the first name "Tom" and last name "Aley" clearly distinguishable.

Tom Aley, President  
Ozark Underground Laboratory, Inc.